

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



ABSTRACT

Integrate In Situ Resource Utilization (ISRU) sub-systems and examine advanced capabilities and technologies to verify **Mars 2024 Forward** architecture precursor pathfinder options:

Integrated spacecraft/surface infrastructure fluid architecture: propulsion, power, life support

- Power system feed and propellant scavenging from propulsion system
- High quality oxygen for life support and EVA

Fluid/cryogenic zero-loss transfer and long-term storage

- Rapid depot-to-rover/spacecraft
- Slow ISRU plant-to-ascent vehicle

Integration of ISRU consumable production

- Oxygen only from Mars atmosphere carbon dioxide
- Oxygen, fuel, water, from extraterrestrial soil/regolith

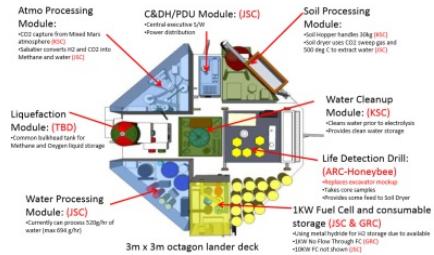
Test bed to evaluate long duration life, operations, maintenance on hardware, sensors, and autonomy

ANTICIPATED BENEFITS

To NASA funded missions:

Provide a focal point for advanced development in separate disciplines and development areas:

- Across the agency: NASA centers and technology development programs (AES, STMD, SBIR, CIF)
- For external partnerships: Other government agencies,



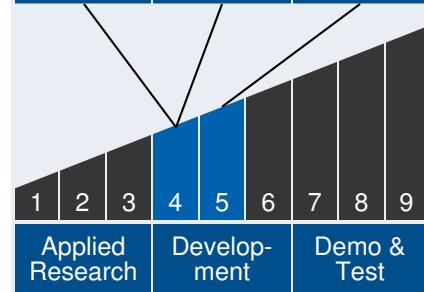
These payloads could be part of a Mars 2026 Mission

Table of Contents

Abstract	1
Anticipated Benefits	1
Technology Maturity	1
Management Team	2
Technology Areas	2
Detailed Description	3
U.S. Locations Working on this Project	4
Image Gallery	5
Details for Technology 1	5

Technology Maturity

At Start: 4 | Current: 4 | At End: 5



Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



industry, academia, international

KSC has been working on ISRU technologies and systems since 1996 (19 years). KSC is participating in the Mars 2024/2026 Pathfinder technology maturation project since it will integrate and test **an ISRU “end to end” system** that will influence future Mars ISRU precursor payloads and human systems.

KSC has substantial ISRU hardware that was shelved and can be completed at a low cost to contribute to the Mars 2024/2026 mission technology development effort.

To NASA unfunded & planned missions:

This is an evolutionary process to refine ISRU technology, increase confidence and scale up to support future sample return or crewed missions to Mars. **There is potential for the Mars 2024/2026 Sample Return Mission to be powered by propellants produced by an ISRU payload and a combined ISRU system test would be the initial step in refining the design and moving towards a flight system demonstrating ISRU.** The Mars 2024/2026 ISRU mission would reduce risk for larger scale human Mars missions. *Mars DRA 5.0 depends on ISRU as an enabling technology.* Similar ISRU hardware could be used at the lunar poles to convert lunar CO into storable methane fuel using local water ice as a source of hydrogen and oxygen.

To the commercial space industry:

Propellant made with ISRU technologies developed by NASA can be made in space and could become a commercial product which will kick start the space economy. Other ISRU technologies will then allow manufacturing in space which will also advance economic activity and human prosperity.

Management Team

Project Manager:

- Nancy Zeitlin

Principal Investigators:

- Robert Mueller
- Anthony Muscatello

Technology Areas

Primary Technology Area:
Human Exploration Destination Systems (TA 7)

└ In-Situ Resource Utilization (TA 7.1)

Other Technology Areas:

- Robotics, Tele-Robotics & Autonomous Systems (TA 4)

Active Project (2015 - 2016)

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



To the nation:

Commercially, the ability to convert CO₂ into methane has a wide ranging applicability as a green technology by converting CO₂ from chemical or power plants, or metabolic CO₂ from closed loop systems into methane to be used as fuel or for power. *On the Moon, similar ISRU systems could use in situ CO to provide propellant in LEO for commercial satellites and spacecraft.*

DETAILED DESCRIPTION

Focus on integration of hardware and concepts developed under and funded from other projects

- Funding for hardware and services to enable integration and testing
- Finish development of shelved hardware to meet integrated test needs (includes KSC umbilical and regolith feed system)**

Increase scope and fidelity of integrated architectures in a stepwise/phased approach

- Initially focus on existing/near-ready hardware for early integration and lessons-learned**
- Allow upgrades as hardware and funding become available.

Examine critical architecture modes of integration and operation:

- Mode 1: Solid Oxide Fuel Cell (SOFC) from LO₂/CH₄ Tanks
- Mode 2: Liquefy & Store ISRU Produced Propellants before Transfer
- Mode 3: Zero-Loss Cryogenic LO₂/CH₄ Fluid Storage and Transfer
- Mode 4: Integrate all Modes of operation for long-term ground test

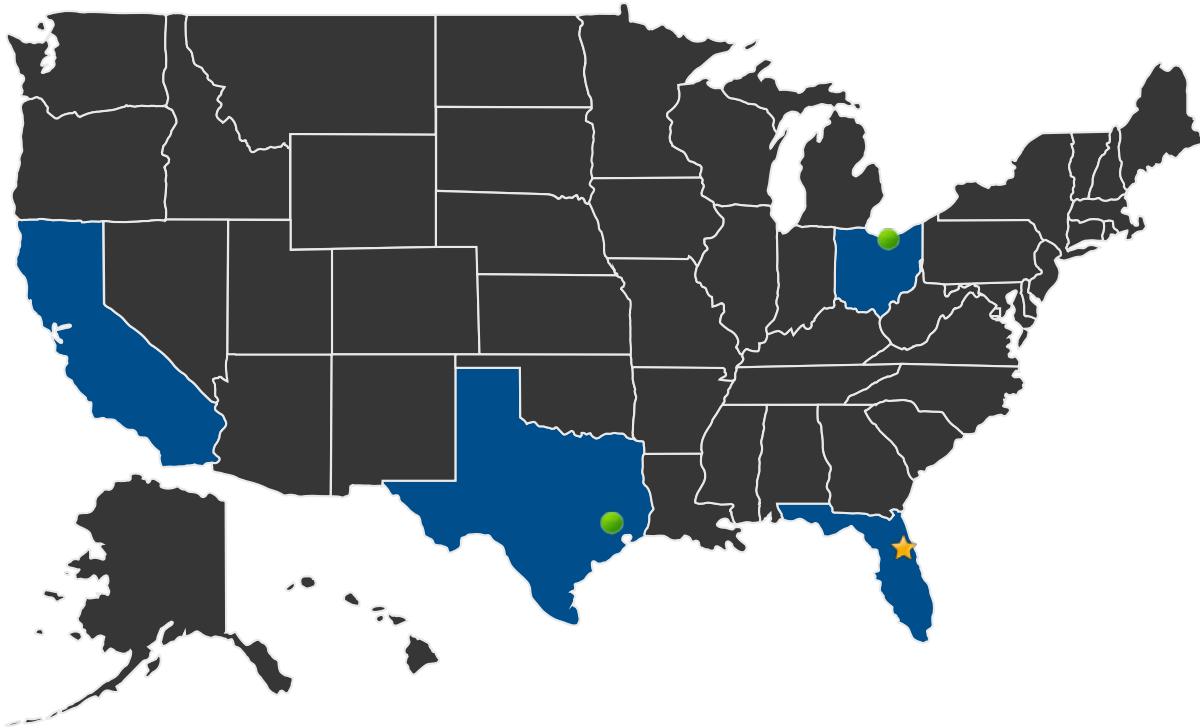
Active Project (2015 - 2016)

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work

★ Lead Center:

Kennedy Space Center

● Supporting Centers:

- Glenn Research Center
- Johnson Space Center

Contributing Partners:

- SpaceX

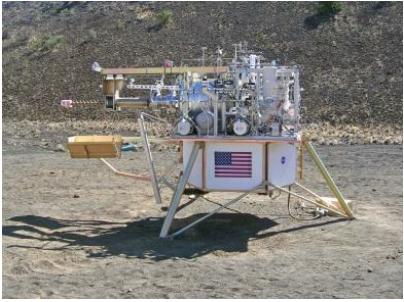
Active Project (2015 - 2016)

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



IMAGE GALLERY



An ISRU payload pre-cursor mission lander



This is a hydrogen reduction ISRU plant for making oxygen from Regolith

DETAILS FOR TECHNOLOGY 1

Technology Title

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources

Technology Description

This technology is categorized as a hardware system for unmanned flight

In order to maximize scientific payload and minimize launch mass, future missions to **Mars** will utilize in situ resource utilization (ISRU) to live off the land, and provide consumables for propulsion, power, and life support. Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources provides a combined test bed to demonstrate this technology. **KSC will complete testing of the existing Atmospheric Processing Module (CO₂ Freezer and the Sabatier (methanation) subsystems-APM) and integrate it with the KSC simulated lander structure. The resulting system would be available for future tests in the Swamp Works Regolith Test Bed or at a propellant test facility.** TRL for a Martian propellant plant is 4 and by performing integrated prototype testing, confidence will be increased in the concept for future mission planning (TRL 5/6).

Active Project (2015 - 2016)

Mars 2024/2026 Pathfinder Mission: Mars Architectures, Systems, & Technologies for Exploration and Resources Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)



Capabilities Provided

In Situ Resource Utilization (ISRU) is the key technology for reducing logistics to another planetary surface for a permanent human presence.

This project is part of an evolutionary technology development process to refine ISRU technology, increase confidence and scale up to support future sample return or crewed missions to Mars.

The Mars ISRU-Propellant integrated system would consist of separate modules for **Atmospheric Processing (APM) (CO₂ Freezer and Sabatier/Methanation Reactor)**, Soil Processing and Water Processing connected to produce H₂ and O₂, enabling methane/oxygen bipropellant production. This project will combine the APM with the Regolith Module and Lander for integrated tests with the other modules.

Potential Applications

There is potential for the Mars 2024/2026 Sample Return Mission to be powered by propellants produced by an ISRU payload and a combined ISRU system test would be the initial step in refining the design and moving towards a flight system demonstrating ISRU.

The Mars 2024/2026 ISRU mission would reduce risk for larger scale human Mars missions. *Mars DRA 5.0 depends on ISRU as an enabling technology.* Similar ISRU hardware could be used at the lunar poles to convert lunar CO into storable methane fuel using local water ice as a source of hydrogen and oxygen.

Commercially, the ability to convert CO₂ into methane has a wide ranging applicability as a green technology by converting CO₂ from chemical or power plants, or metabolic CO₂ from closed loop systems into methane to be used as fuel or for power. *On the Moon, similar ISRU systems could use in situ CO to provide propellant in LEO for commercial satellites and spacecraft*

Performance Metrics

Metric	Unit	Quantity
Produce oxygen	liters	10
Extract water from Regolith	liters	15